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LANGLEY WORKING PAPER

SUMMARY OF NASA SUPPORT OF THE F-111 DEVELOPMENT PROGRAM

Part I - December 1962 - December 1965

By the Staff of the NASA Research Centers

Langley Research Center
Langley Station, Hampton, Virginia

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Working Paper No. 246

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INTRODUCTION

The F-111 is a biservice, multimission, tactical aircraft being developed for the Air Force and Navy by General Dynamics and Grumman. The general arrangement of the F-111 is shown in figure 1. This aircraft, through the use of the "variable sweep wing" concept, offers the possibility of combining a wide range of mission capabilities into a single aircraft. The F-111 is a direct outgrowth of the Langley Research Center's variable sweep research which began in 1947. The early research culminated in the X-5 variable sweep research airplane which demonstrated the advantage and feasibility of in-flight sweep variation. The X-5 utilized the translating wing concept to offset the longitudinal stability variation with sweep changes. Later Langley research beginning in 1958 resulted in the "outboard pivot" concept which eliminated the need for wing translation and led to the TFX (F-111) concept. A chronology of the NACA/NASA variable sweep research effort and direct support of the TFX up to the awarding of the contract to General Dynamics/Grumman on November 24, 1962, is presented in reference 1.

Since the awarding of the contract, the Langley, Ames, Lewis, and Flight Research Centers have been actively supporting the F-111 development program. Because of the strong NASA interest in this aircraft and the large magnitude of NASA support involved, it was felt desirable to document this support. The purpose of this paper therefore is to present a brief summary of the NASA support, in chronological order, through December 1965, beginning with the awarding of the contract in November 1962.

SUMMARY OF NASA SUPPORT

This summary deals only with the direct support of the F-111 during the above period and does not include NASA variable sweep

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research. During this time period NASA support of the F-111 development program consisted primarily of wind tunnel testing and analysis and participation on various F-111 advisory groups. The wind tunnel support was contributed by three research centers, Ames, Langley and Lewis, and a brief summary is presented in the following table. The support is presented in terms of tunnel occupancy time in hours during working shifts.

RESEARCH CENTER	YEAR			TOTAL
	1963	1964	1965	
Langley	4,839	5,640	4,346	14,825
Ames	394	2,586	1,408	4,388
Lewis		720		720
TOTALS	5,233	8,946	5,754	19,933

It will be noted that for the three years listed a total of nearly 20,000 tunnel occupancy hours were devoted to the F-111. A total of 17 wind tunnel facilities were utilized and a summary by facility is presented in Table I. This is the most extensive wind tunnel support ever provided for one aircraft by the NASA or NACA. It should be noted that NASA support of the current and proposed version of the F-111 is continuing and is expected to continue for several years.

Descriptions of the various wind tunnel test periods and other support activities are presented in the following section.

DETAILS OF NASA SUPPORT

A brief description of each wind tunnel test period and other support activities is presented in this section. The hours listed at the end of each test period represent the total tunnel occupancy time in hours during working shifts and therefore include both running time and time for model changes. In general, tests were run on a two 8-hour shift per day basis. The other support activities described have been limited primarily to participation on various advisory groups and does not include the many pre-test meetings and technical consultations.

1962

December 11, 1962 - (LRC)

Representative of General Dynamics visited the Langley Research Center to discuss the possibility of Langley wind tunnel support

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during the F-111 development program. They were informed that Langley would review their proposed wind tunnel program and contact the Air Force with regard to the extent to which Langley would be able to provide wind tunnel support.

December 19, 1962 - (LRC)

General Dynamics and Grumman representatives visited the Langley Full-Scale Research Division to solicit recommendations with regard to the supersonic performance characteristics of the F-111. The Langley representatives made recommendations in the areas of supersonic drag due-to-lift and trim drag. It was recommended:

- (1) That the spanwise camber proposed by General Dynamics (an effort to improve the low altitude transonic dash) be eliminated since it would not be expected to significantly improve the low altitude performance and would increase the supersonic drag due-to-lift and trim drag, thereby penalizing the supersonic altitude performance, and
- (2) That the supersonic trim drag be reduced and maneuverability be increased by selecting a more favorable wing pivot location, thereby reducing the longitudinal stability variation with sweep.

December 26, 1962 - (Ames)

A meeting at Ames was held with Mr. P. Truax of General Dynamics and Mr. W. Anderson of Ames Research Center to discuss air induction system development for the F-111. Overall system concepts and flow field survey test procedures were discussed.

1963

January 4, 1963 - (LRC)

Langley informed the Chief, Air Force Systems Command Liaison Office that the Langley Research Center would provide F-111 wind tunnel support in the following areas:

- | | |
|---------------------------------|----------------------------------|
| (1) Nacelle-fuselage base tests | (6) Dynamic stability tests |
| (2) High-speed force tests | (7) Free-flight model tests |
| (3) Transonic speed force tests | (8) Component flutter tests |
| (4) Aeroelastic loads tests | (9) Complete model flutter tests |
| (5) Spin tests | |

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It was also pointed out that the 1/15 scale model was too large for the Cornell and Langley 8-foot transonic pressure tunnels or the Langley UPWT and that it would be difficult to schedule sufficient time in large transonic and supersonic facilities. It was therefore recommended that a 1/24 scale model be constructed for the transonic and supersonic tests.

January 4 - 16, 1963 - (ARC 6- by 6-foot WT)

A 1/20-scale model of the F-111 proposal configuration was tested in the Ames 6- by 6-foot wind tunnel to determine drag and longitudinal stability characteristics in the Mach number range from 1.2 to 2.2. (84 hours)

January 21 - February 1, 1963 - (LRC 26-in. TBT)

Flutter trend models were tested at Mach numbers from 0.55 to 1.28 in the Langley 26-inch transonic blowdown tunnel. The purpose of these tests was to determine the general shape of the flutter boundary for the isolated wing and tail surfaces of the F-111. (160 hours)

February 25 - March 15, 1963 - (LRC 26-in. TBT and 20-in. VST)

Flutter trend models were tested in the Langley 26-inch transonic blowdown tunnel and the 20-inch variable supersonic tunnel to determine the shape of the flutter boundary for the isolated wing and tail surfaces up to a Mach number of 3.0. Model damage due to very rough transient flow conditions and strong shocks during start in VST indicated need for supersonic test facility having less severe start conditions. (196 hours)

March 18 - April 2, 1963 - (LRC - UPWT)

The initial tests of F-111 configuration 12RB-008 in the Langley Unitary Plan Wind Tunnel in the Mach number range from 1.6 to 2.5 were made during this period. Results indicated a high static margin and nonlinear control characteristics which resulted in a maneuver capability much less than the proposal. A deficiency in directional stability was also indicated. The tests indicated a higher level of minimum drag but a lower level of drag due-to-lift. (305 hours)

March 25 - April 1, 1963 - (ARC 11-ft. TPT)

Tests of the 1/6 scale flow field model were made in the Ames 11-foot transonic pressure tunnel to determine the flow field characteristics in the vicinity of the inlets. Tests were made in the Mach number range from 0.7 to 1.4. (104 hours)

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April 9 - May 1, 1963 - (LRC 16-ft. TT)

Hot jet tests at transonic speeds of a 1/9 scale nozzle mounted on an isolated nacelle were made in the Langley 16-foot transonic tunnel to determine the effectiveness of the blow-in-door ejector nozzle and the external pressure drag on the nozzle shroud. The nacelle used in these tests was somewhat more representative of the F-111 afterbody lines than the P and W model. The results were in essential agreement with the P and W results but with some indication that there might be some installation effect on the actual airplane. (270 hours)

April 22 - May 13, 1963 - (LRC 8-ft. TPT)

Tests of a 1/24 scale model of the F-111 (configuration 12RB-008) were made in the Langley 8-foot transonic pressure tunnel (test 272) during this period. Results indicated that the transonic drag was considerably higher than the proposal level and that a large drag reduction must be accomplished to meet mission requirements. Local contour modifications recommended by LRC to improve the area distribution provided some transonic drag reduction but it was apparent that some major modifications would be required. It was therefore recommended by the Langley 8-foot staff that the cant in the tail pipes be eliminated to reduce the severe afterbody closure, that a longer interengine fairing be added, and that a twisted horizontal tail be used to provide favorable interference.

Regarding longitudinal stability, the results indicated a rather large increase in stability (approximately 36 percent of the $16^\circ \bar{c}$) as the wing of sweep increased from 16° to 72.5° and the possibility of some instability at subsonic speeds under certain loading and wing sweep conditions. (192 hours)

April 26 - May 21, 1963 - (LRC)

During this time period several discussions between Langley personnel and General Dynamics were held to determine methods of improving the supersonic maneuverability. Langley emphasized the importance of wing pivot location and suggested a change in pivot location and a forward shift of the wing as a solution to the maneuverability problem. Both Langley and General Dynamics estimates indicated that the modification should result in some improvement in supersonic radius and large improvements in maneuverability but that some loss in low altitude dash performance might be expected. It was decided that the modified wing suggested by Langley would be built and tested. During this period it was also established that the rather large difference in maneuver capability computed by General Dynamics and Langley was due primarily to the fact that General Dynamics used a linear extrapolation of low deflection control effectiveness data.

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May 6 - 9, 1963

A wind tunnel planning and coordination meeting for the F-111 program was held at WPAFB. NASA was represented by R. F. Huntsberger (ARC) and R. W. Boswinkle, Jr., and E. C. Polhamus (LRC).

May 14 - 17, 1963 - (LRC UPWT)

Supersonic tests of the flutter trend models were made in the Langley Unitary Plan Wind Tunnel. (64 hours)

May 22 - May 25, 1963

T. G. Ayers of LRC 8' TPT visited Cornell Aeronautical Labs to monitor wind tunnel tests of 1/24 scale model of F-111. These tests were made to resolve drag differences which occurred between the 1/15 scale model in C.A.L. and the 1/24 scale model in LRC 8' TPT. It was also noted, at this time, that an extremely large, blunt model support was being used in the Cornell tunnel which would affect the drag measurements obtained near $M = 1.00$.

May 31 - July 19, 1963 - (LRC 16-ft. TT)

A 1/12 scale complete model utilizing hydrogen peroxide to provide hot jets was tested in the Langley 16-foot transonic tunnel to determine the nozzle performance in the actual F-111 flow field and the effect of jet interference on the aerodynamic characteristics of the aircraft. Results indicated the possibility of sizable adverse installation effects on nozzle performance but due to model clearance problems, balance flexibility, etc., the test results were considered unreliable. Pressure measurements on the shroud indicated that the installed shroud pressure drag was approximately twice the uninstalled value. The model was returned to Fort Worth to be redesigned and rebuilt to eliminate the mechanical problems. (560 hours)

June 6 - July 19, 1963 - (LRC UPWT)

Supersonic tests of configuration 12RB-008 were continued in the Langley Unitary Plan Wind Tunnel to study directional stability and maneuverability problems. Tests of the Langley wing modification indicated a large increase in maneuverability which would allow the aircraft to approach the proposed maneuverability. On the basis of the change in maximum cross-sectional area, some transonic drag penalty would be expected with the modified wing. However, in view of the associated improvement in forebody area distribution, it was felt that the penalty may be small and that transonic tests were warranted. (512 hours)

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June 20, 1963 - (LRC)

NASA/LRC received a request from the F-111 System Program Office for LRC participation on an F-111 Aerodynamics Consulting Group. The purpose of this group was "to review the current aircraft configuration from the aerodynamic viewpoint and to make recommendations for necessary corrections to the Deputy for Engineering, F-111 Engineering Office." Messrs. E. C. Polhamus and M. L. Spearman were appointed LRC representatives with Messrs. R. P. Bielat and A. W. Robins as alternates.

June 24, 1963 - (LRC)

A meeting between Langley, F-111 SPO, and General Dynamics representatives was held at Langley to discuss the results of the supersonic tests in the LRC UPWT. The NASA representatives pointed out that the test results indicated problems in the areas of drag, maneuverability and directional stability. The revised wing pivot position was discussed as a means of improving the maneuverability but because of a possible transonic drag penalty, the engineering effort involved and attendant schedule slippage, the Air Force cancelled further studies of the wing modification.

July 17, 1963 - (LRC)

General Dynamics and Grumman representatives visited LRC to discuss transonic drag differences between the Cornell 8-foot transonic pressure tunnel and the Langley 8-foot transonic pressure tunnel tests of the 1/24 scale model of the F-111. Members of the Langley 8-foot tunnel staff had investigated these differences and had come to the conclusion that the lower drag measured in the Cornell facility was probably due to an interference effect associated with the large, blunt support sting used in the Cornell tests. Langley offered to investigate this by testing a mockup of the Cornell support system and General Dynamics agreed to build the necessary parts.

July 22 - 23, 1963 - (LRC 4-ft. SPT)

Tests were made in the Langley 4-foot supersonic pressure tunnel to determine the effect of Reynolds number and transition strips on the supersonic drag of the F-111 (configuration 12RB-008). (32 hours)

July 29 - August 12, 1963 - (LRC 26-in. TBT)

Dynamically similar flutter models of the preliminary wing design were tested in the Langley 26-inch transonic blowdown tunnel in order to establish stiffness requirements for flutter prevention at transonic speeds. (180 hours)

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July 30 - August 2, 1963

The first meeting of the F-111 Aerodynamic Consulting Group (Air Force, Navy, NASA) was held at the General Dynamics Plant, Fort Worth, Texas, on July 30 through August 2, 1963. The NASA attendees were Messrs. M. L. Spearman and E. C. Polhamus. After a review of the available wind tunnel data and corrections that must be applied to represent full scale aircraft conditions the group concluded that the transonic performance, in particular, would be considerably below the requirements. The group therefore recommended that the aft end modifications suggested by NASA/LRC be studied. Additional studies of the directional stability were also recommended.

August 12 - September 5, 1963 - (LRC 7- by 10 HST)

During this period the damping-in-roll characteristics were determined at subsonic and transonic speeds in the Langley 7- by 10-foot high speed tunnel using a 1/22 scale model. (272 hours)

August 19 - 27, 1963 - (LRC UPWT)

Tests were made in the Langley Unitary Plan Wind Tunnel to determine the effect of the bomb bay cavity and doors on directional stability. Various methods of improving the supersonic directional stability were investigated. (128 hours)

August 19 - September 6, 1963 - (LRC 16-ft. TDT)

A dummy model of the F-111 complete airplane flutter model was tested in the Langley 16-foot transonic dynamics tunnel to check the wind tunnel suspension system to be used for future tests of the complete airplane flutter model. (240 hours)

September 4 - 6, 1963 - (LRC UPWT)

Supersonic tests were made in the Langley Unitary Plan Wind Tunnel to determine the aerodynamic characteristics of configuration 12RB-140 which incorporated the fuselage modification designed to reduce inlet flow distortion. Results indicated an increase in drag. (48 hours)

September 10 - 23, 1963 - (LRC 8-ft. TPT)

The 1/22 scale model of the F-111 was tested at subsonic and transonic speeds in the Langley 8-foot transonic pressure tunnel to determine the aerodynamic damping characteristics in pitch and yaw. (144 hours)

September 16 - October 4, 1963 - (LRC 16-ft. TDT)

A 1/8 scale semispan flutter model of the F-111 was tested in the Langley 16-foot transonic dynamics tunnel in the Mach range from 0.3 to 1.13. The primary purpose of these tests was to establish the extent

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to which the horizontal tail flutter speed is affected by the presence of the fully sweptback wing. The results indicated only minor effects. (240 hours)

September 30 - October 2, 1963

The second meeting of the F-111 Aerodynamic Consulting Group (Air Force, Navy, NASA) was held September 30 - October 2, 1963, at the General Dynamics Plant, Fort Worth, Texas. NASA representatives were Messrs. M. L. Spearman, R. P. Bielat, and E. C. Polhamus. The group found that the large drag difference between the Government and the contractor still existed. It recommended that the 1/12 scale nacelle-fuselage-base model be used to investigate the modified interengine fairings recommended earlier by NASA/LRC.

October 4 - November 7, 1963 - (LRC 8-ft. TPT)

During this period special tests were made in the Langley 8-foot transonic pressure tunnel to determine the cause of the transonic drag differences between the Langley and Cornell tests of configuration 12RB-008. A mockup of the Cornell "double roll" support system was tested and indicated a large buoyancy effect which accounted for the low transonic drag in the Cornell tunnel. Tests of the current configuration (12RB-140B) were also made in the Langley 8-foot transonic tunnel during this period and indicated a further increase in drag due primarily to an increase in cross-sectional area caused by fuselage changes required to reduce flow distortion at the inlet. The straightened tail pipe and twisted horizontal tail suggested by Langley (see April 22 - May 13, 1963) were tested and indicated that some of the dash performance could be recovered by these modifications. (432 hours)

October 14 - 18, 1963 - (LRC 26-in. TBT)

Dynamically similar flutter models of the preliminary horizontal tail design were tested in the Langley 26-inch transonic blowdown tunnel. These test results were questionable because they did not correlate previous flutter data and because the models did not adequately scale all airplane parameters. (80 hours)

November 4 - 18, 1963 (ARC 11- by 11-foot WT)

Early estimates of the F-111 static aeroelastic effects indicated that very large modifications to rigid model stability and control parameters would be necessary. Furthermore, the aerodynamic interaction effects of elastic deformations of the closely coupled wing and horizontal tail are difficult to determine analytically or with rigid model testing. A 1/15-scale aeroelastic model was constructed with stiffness simulating the structural elasticity of the full-scale airplane. Tests were conducted in the Ames 11- by 11-foot wind tunnel to determine the effects of flexibility on major stability and control parameters, and to determine flexible airplane component loads characteristics for use

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in verifying structural design loads. The tests covered the Mach number range from 0.8 to 1.4 at dynamic pressures of 320 PSF to 960 PSF. Results clearly indicated the decrease in effectiveness of the various lifting surfaces with increasing dynamic pressure and pitch attitude. The effects of aeroelasticity on the stability characteristics were somewhat larger than those predicted by General Dynamics, indicating adjustments in estimating techniques were necessary. (206 hours)

November 7 - 27, 1963 - (LRC UPWT)

Supersonic tests of configuration 12RB-140 were made in the Langley Unitary Plan Wind Tunnel to determine the high-speed characteristics of selected configurations from the October 4 - November 7, 1963, Langley 8-foot transonic tunnel tests. The effects of the short-span vertical tail and single and double hinged bomb-bay doors on directional stability were also investigated. (224 hours)

December 4 - 13, 1963 - (LRC UPWT)

Tests of the 1/22 scale model of the F-111 were made in the Langley Unitary Plan Wind Tunnel to determine the damping in pitch and yaw in the Mach number range from 1.7 to 2.5. (80 hours)

December 16, 1963 - January 10, 1964 - (LRC 16-ft. TT)

Tests were made of a 1/6-scale inlet model of the F-111 in the Langley 16-foot transonic tunnel. The effects of nose shape (Air Force and Navy), spike configuration, bleed, bombs, fuel tanks and open bomb-bay doors were investigated. (400 hours)

1964

January 10-14, 1964 (LRC 16-ft. TT)

Tests of a "blockage" model were made in the Langley 16-foot transonic tunnel to evaluate the blockage effects for full-scale inlet tests at AEDC. (32 hours)

January 14 - 16, 1964

The third meeting of the F-111 Aerodynamics Consulting Group met January 14 - 16, 1964, at the contractors plant in Fort Worth, Texas. Langley, Ames and Flight Research Centers were represented.

February 4 - March 5, 1964 - (LRC UPWT)

During this period tests were made in the Langley Unitary Plan Wind Tunnel to study the supersonic stability characteristics of the F-111A. (360 hours)

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February 24 - March 13, 1964 - (LRC 26-in. TBT and 20-in. VST)

Dynamically similar flutter models of the isolated wing and horizontal tail were tested in the Langley 26-inch transonic blowdown tunnel and 20-inch variable supersonic tunnel. The then current horizontal tail design had an inadequate flutter margin of safety at low supersonic speeds, and studies to increase the flutter speed by varying planform and stiffness were made. (180 hours)

February 28 - March 10, 1964 (LRC 16-ft. TT)

Additional tests of the 1/6-scale inlet model of the F-111 were made in the Langley 16-foot transonic tunnel. The inlet, cowl, and spike geometry were revised since the first series of transonic inlet tests. (264 hours)

March 16 - May 8, 1964 - (ARC 11- by 11-foot WT and 9- by 7-foot WT)

Results of the November 4-18, 1963, aeroelastic test confirmed the validity of the testing technique and the model structural integrity. Extensive tests were then conducted in the Ames 11- by 11-foot and 9- by 7-foot wind tunnels to cover additional configurations and test conditions. This investigation was for a Mach number range from 0.8 to 2.5 at dynamic pressures of 250 PSF to 960 PSF. (474 hours)

March 18 - April 24, 1964 - (LRC UPWT)

Tests of the supersonic stability characteristics of the Air Force version were continued in the Langley Unitary Plan Wind Tunnel. (464 hours)

March 24, 1964

Messrs. C. J. Donlan and E. C. Polhamus of Langley accompanied by Dr. R. Bisplinghoff of OART visited Assistant Secretary of the Air Force, Dr. A. Flax, to discuss F-111 wind-tunnel tests and performance problems. The Langley representatives pointed out that the contractors performance estimates were very optimistic and based on questionable wind-tunnel data. They indicated that the 1/20-scale model should be tested in the Langley 16-foot transonic tunnel to assure interference free data and Dr. Flax agreed to make the model available. The Langley representatives also recommended that tests in the Langley 16-foot transonic tunnel be made to determine the benefits of the aft-end modifications suggested by Langley, the closure corrections and the nozzle performance before the May 15, 1964 evaluation of the airplane. It was also suggested that the Navy wing be used on the Air Force airplane.

April 6, 1964 - (ARC)

A review and discussion of the F-111 propulsion system development program was held at Ames. The presentation was made by Mr. L. H. Schrieber and Mr. F. Thebiay, of General Dynamics. Ames was represented by Messrs. E. Perkins, W. Anderson, N. Sorenson, and A. Jones.

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April 7 - May 7, 1964 - (LeRC 8 x 6 ft. SWT)

Inlet performance and control signals were obtained with the 1/6-scale model of the F-111 over the Mach number range 1.3 to 2.0. (320 hours)

April 8 - 10, 1964 - (ARC 11- by 11-foot WT)

A 1/20-scale model of the F-111 was tested in the Ames 11- by 11-foot wind tunnel to further define the drag and longitudinal stability characteristics in the Mach number range from 0.7 to 1.4. In order to minimize the afterbody distortion of the model, an extremely slender sting was used. As a result, excessive lateral oscillations of the model caused poor repeatability of the data and failure of the balance side-force gages. (40 hours)

April 9 - 10, 1964 - (Aerodynamics Consulting Group)

The fourth meeting of the F-111 Aerodynamics Consulting Group was held at General Dynamics, Fort Worth, Texas, on April 9 - 10, 1964. NASA members present were M. L. Spearman and E. C. Polhamus. It had been recommended by General Dynamics that each meeting be limited to a small informal group discussing only one technical area. Therefore, the fourth meeting was limited to stability and control with no formal presentation by the contractor. The meeting dealt primarily with items in the weight reduction program which might have an effect on the stability and control characteristics. Also discussed was the possibility of improving the supersonic maneuverability.

April 27 - May 29, 1964 - (LRC 26-in. TBT and 20-in. VST)

Dynamically similar flutter models of the vertical tail were tested in the Langley 26-inch transonic blowdown tunnel and in the 20-inch variable supersonic tunnel. Most of the VST test time was required to develop a model shielding system which would prevent model damage during tunnel start; however, the system developed proved only partially successful. (240 hours)

April 30 - May 7, 1964 - (Schriever - Schoech Briefing)

During this time period, NASA representatives participated in several meetings in connection with a presentation to General Schriever and Admiral Schoech on the F-111 weapon system performance.

On April 30, 1964, R. P. Bielat, and E. C. Polhamus attended a meeting at the Bureau of Naval Weapons called by the Air Force for the purpose of discussing the latest aerodynamic information with Navy, Air Force, NASA and General Dynamics in preparation for the presentation to General Schriever and Admiral Schoech. Air Force, Navy and NASA

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representatives agreed that the contractor's use of the Cornell 1/20-scale transonic drag data could not be justified in light of other data and the fact that the nature of the data was highly suggestive of a tunnel flow distortion.

On May 6, 1964, NASA representatives attended a meeting at General Dynamics. The primary purpose of this meeting was for General Dynamics, Air Force, and the Navy to finalize their presentation for the Schriever-Schoech-Briefing.

On May 7, 1964, the NASA representatives (M. R. Nichols, R. F. Huntsberger, R. P. Bielat, M. L. Spearman, and E. C. Polhamus) attended the briefing for General Schriever and Admiral Schoech. NASA made the following presentations as a part of the briefing:

- (1) An Outline of NASA Support and an Analysis of the Transonic Drag - E. C. Polhamus (LRC)
- (2) A Summary of Supersonic Stability and Control Studies - M. L. Spearman (LRC)
- (3) A Summary of Aeroelastic Effects and Future Ames Support - R. F. Huntsberger (ARC)

With regard to the performance problem, it was recommended that the aft end be improved and that the Navy wing be added to the Air Force airplane.

May 7 - 15, 1964 - (ARC 6- by 6-foot WT)

The urgency of determining the drag and longitudinal stability characteristics of an up-to-date version of the F-111 at an early date resulted in attempts to test the 1/20-scale model at supersonic speeds in the Ames 6- by 6-foot wind tunnel. However, poor repeatability of data was also experienced at supersonic speeds in a manner similar to the April transonic investigation. Failure of two balances resulted in early termination of the test. (100 hours)

May 11 - July 3, 1964 - (ARC 9- by 7-foot, 11- by 11-foot, and 12-foot WT)

A 1/12-scale rigid loads model of the F-111 was tested in the Ames 9- by 7-foot, 11- by 11-foot, and 12-foot wind tunnels. The purpose of the test was to determine external store loads, weapons bay door loads, control surface hinge-moments, and pressures on the fuselage, wing and tail sections. The investigation covered the Mach number range from 0.25 to 2.50 at dynamic pressures of 150 PSF to 650 PSF. (560 hours)

May 19 - 28, 1964 - (LRC UPWT)

Additional tests of the supersonic stability characteristics of the F-111A using the 1/24-scale model were made in the Langley Unitary Plan Wind Tunnel. (120 hours)

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May 21 - 26, 1964 - (LRC 8-foot TPT)

Tests of the 1/20-scale model (with kidney bleed exit) were made in the Langley 8-foot transonic pressure tunnel. Tests were run at reduced pressures and avoided the model oscillation problem encountered in the 16-foot transonic tunnel. The results were in general agreement with the Ames tests and again indicated that the contractor was basing the transonic performance estimates on drag levels which were too low. Studies of the shock reflection characteristics and grit drag were also made during this test period. (288 hours)

May 25 - June 5, 1964 - (ARC 12-foot WT)

A 1/12-scale model of the F-111B was tested in the Ames 12-foot wind tunnel to select the optimum high-lift devices for the landing configuration and to determine the effect of Reynolds number on the stability characteristics and the maximum lift of the selected configuration. The investigation covered the Mach number range from 0.14 to 0.30 at Reynolds numbers of 0.95 to 6.38 millions per foot. (160 hours)

May 26 - June 6, 1964 - (LRC 16-ft. TT)

In an attempt to provide data with which to accurately identify valid Mach number regions for data obtained in smaller tunnels, tests were made in the Langley 16-foot transonic tunnel using the 1/20-scale model. Due to the high dynamic pressures associated with this atmospheric tunnel and the extremely flexible sting support associated with the 1/20-scale model, valid data could not be obtained. (184 hours)

June 7 - 17, 1964 - (LRC 8' TPT)

1/20-scale model was returned to the 8' TPT for tests to determine the missile drag of the F-111B. (120 hours)

June 8 - 12, 1964 - (ARC 12-foot WT)

A 1/24-scale model of the F-111 was tested in the Ames 12-foot wind tunnel at large angles-of-attack, angles-of-yaw, and Reynolds numbers for Mach numbers of 0.1 and 0.2. This investigation was in support of the Langley spin test program. Appropriate forebody modifications were established to simulate, at the low Reynolds numbers of spin-tunnel investigations, the cross-flow characteristics approximating the high Reynolds number conditions of full-scale flight. (80 hours)

June 17 - 23, 1964 - (LRC 16-ft. TT)

During this period an attempt to obtain valid data on the 1/20-scale model in the Langley 16-foot transonic tunnel by use of a damper to minimize model oscillations was made to no avail. (56 hours)

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June 29 - July 24, 1964 - (ARC 6- by 6-foot WT)

A 1/20-scale model of the F-111 was tested in the Ames 6- by 6-foot wind tunnel to determine the drag and longitudinal stability characteristics in the Mach number range of 1.2 to 2.2. Navy and "stretch" versions were tested as well as the Air Force version. During this and following investigations using the 1/20-scale model, a larger and stronger balance was used than for previous investigations, resulting in smaller model oscillations and a significant improvement in data repeatability. (320 hours)

July 7 - July 21, 1964 - (LeRC 10 x 10 foot SWT)

Effects on inlet performance of a variety of protuberances on the fuselage (used to contain reconnaissance equipment) were determined with the 1/6-scale model of the RF-111 over the Mach number range 2.0 to 2.5 . (240 hours)

July 13 - 15, 1964 - (SPO Meeting)

During this period, NASA representatives (R. F. Huntsberger, R. P. Bielat, and E. C. Polhamus) participated in meetings at the F-111 System Program Office, Wright-Patterson Air Force Base. Purpose was to prepare presentation of F-111B to be given to Commander AFSC and Chief, Naval Material. NASA was requested to report on wind-tunnel tests. Mr. Huntsberger reviewed the Ames high-lift studies and E. C. Polhamus reviewed the Langley drag studies.

July 15 - September 2, 1964 - (LRC 16-ft. TT)

Phase II tests of the 1/12-scale hot jet, propulsion model were made in the Langley 16-foot transonic tunnel. These tests established the magnitude of the previously (Phase I) indicated nozzle thrust deficiency associated with the adverse fuselage afterbody flow field. In addition the tests substantiated the high external shroud drag indicated in the Phase I tests. (560 hours)

July 20 - 24, 1964 - (LRC UPWT)

Supersonic stability tests of the 1/24-scale model were continued in the Langley Unitary Plan Wind Tunnel. (80 hours)

July 21, 1964 - January 12, 1965 - (Sting Support Construction)

During this period NASA/LRC negotiated for construction of an improved sting support for the 1/20-scale model to provide more reliable data at high dynamic pressures. Due to a shortage of Air Force funds, NASA/LRC funded a contract with General Dynamics for construction of this special sting support. The new sting was

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used for both drag studies and special tests requested by the F-111 Nozzle Committee.

July 28 - August 4, 1964 - (LRC 8 ft. TPT)

Transonic tests of a 1/24-scale model of the RF-111A were made in the LRC 8 ft. TPT. (96 hours)

August 1 - August 15, 1964 - (LeRC 8 x 6 ft. SWT)

Effects on inlet performance of a variety of protuberances on the fuselage (used to contain reconnaissance equipment) were determined with the 1/6-scale model of the RF-111 over the Mach number range 1.3 to 2.0. (160 hours)

August 3 - 21, 1964 - (ARC 12-foot WT)

A 1/12-scale model of the F-111A was again tested in the Ames 12-foot wind tunnel to obtain the landing configuration stability characteristics of the F-111 airplane. High-lift devices were further optimized for application to later production airplanes. The tests were conducted at Mach numbers of 0.17 and 0.20. (240 hours)

August 6 - 14, 1964 - (LRC UPWT)

Studies of the supersonic stability characteristics of the Reconnaissance version of the F-111A were made in the Langley Unitary Plan Wind Tunnel. (80 hours)

August 17 - 26, 1964 - (LRC 16-ft. TDT)

Flutter clearance tests of empennage of 1/8-size complete flutter model were made in Langley 16-ft. transonic dynamics tunnel. Flutter was obtained at unexpectedly low speeds in the low supersonic Mach number range. However, later comparison of model and airplane characteristics indicated a difference in simulating the tail actuator structure caused the low flutter speed. (80 hours)

August 27 - September 16, 1964 - (LRC UPWT)

Supersonic studies of the Reconnaissance version were continued in the Langley Unitary Plan Wind Tunnel. (112 hours)

September 7 - 11, 1964 - (ARC 11- by 11-foot WT)

A 1/12-scale model of the aft portion of the F-111 was tested in the Ames 11- by 11-foot wind tunnel to determine the efficiencies of several exhaust nozzles and shrouds in the Mach number range from 0.7 to 1.2 utilizing a cold air technique. (60 hours)

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September 17, 1964 - (LRC UPWT)

Tests to determine the supersonic characteristics of the SAC version of the F-111 were made in the Langley Unitary Plan Wind Tunnel. (16 hours)

September 18 - 24, 1964 - (LRC 16-ft. TT)

Additional tests of the 1/6-scale inlet model of the F-111 were made in the Langley 16-foot transonic tunnel. The effects of an extended nose (for RF-111A), a weapons bay pod, a fuselage mounted bomb, and bleed were investigated. (112 hours)

September 21 - October 30, 1964 - (ARC 11- by 11-ft. and 6- by 6-ft. WT)

The drag and longitudinal characteristics of the F-111 Air Force, Navy, and "stretch" configurations were investigated for Mach numbers from 0.60 to 2.2 in the Ames 11- by 11-foot and 6- by 6-foot wind tunnels. Test variables included wing sweeps, tail deflections, and external store arrangements. During these investigations 1/20-scale models were used to assure interference free data and the results demonstrated that the low values of transonic drag obtained in the Cornell tunnel were invalid. (416 hours)

September 23 - 30, 1964 - (LRC 26-in. TBT)

Dynamically similar flutter models of the horizontal tail were tested in the Langley 26-inch transonic blowdown tunnel. These results verified previous small model results as opposed to the low flutter speed obtained with the 1/8-size empennage model in August 1964. Studies of the new, lightweight tail (SWIP) design indicated that a more forward pitch axis location could sizably reduce the stiffness requirements for flutter prevention. (80 hours)

September 24 - October 1, 1964 - (LRC UPWT)

Stability tests of the F-111A were made in the Langley Unitary Plan Wind Tunnel. (96 hours)

September 29 - October 1, 1964 - (GD/FW)

NASA provided consultants for meeting at General Dynamics called by General Zoeckler for the purpose of arriving at a common set of data and other inputs for use by both the Air Force and Navy in predicting the weight and performance of the F-111B for the next Engineering Management Review. NASA representatives serving as consultants were E. C. Polhamus, J. F. Runckel, M. L. Spearman, and R. F. Huntsberger.

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October 1964 - May 1966 - (LRC Spin Tunnel)

Because of the intermittent type of testing no attempt will be made to itemize the Langley spin tunnel test periods. The tests were made during a large number of test periods covering the above period. The test hours listed however cover only the actual time devoted to the F-111.

Spin tunnel tests were made by the Langley dynamic stability branch on 1/40-scale models of the F-111A/B airplane to determine the spin and recovery characteristics. The tests were made for a scaled weight condition of 50,000 pounds at several center-of-gravity locations from fuselage station 516 to 540, and a simulated altitude of 30,000 feet. Tests included wing sweep angles of 20°, 26°, 50°, and 72.5°. (1574 hours)

October 5 - 22, 1964 - (ARC 9- by 7-foot WT)

A 1/15-scale model of the F-111A was tested in the Ames 9- by 7-foot wind tunnel to determine the lateral and longitudinal stability characteristics at high Reynolds numbers for Mach numbers from 1.7 to 2.5. (136 hours)

October 7 - December 11, 1964 - (LRC 16-ft. TT)

Phase III tests of the 1/12-scale hot jet, propulsion model were made in the Langley 16-foot transonic tunnel. This extensive test series included studies of a wide range of blow-in-door ejector nozzle geometry suggested by both Pratt and Whitney and General Dynamics in an attempt to solve the nozzle thrust and flutter problems. Also included were NASA/LRC initiated studies directed towards reducing the large base drag associated with the short inter-engine fairing. These studies consisted of longitudinal pressure surveys between the jets and the testing of a longer and wider inter-engine fairing design based on the pressure surveys.

Only minor improvements were obtained from the nozzle studies. However, an improvement in thrust minus drag equivalent to approximately 20 counts of drag was obtained with the Langley interengine fairing. Afterbody closure drag corrections were also obtained. (752 hours)

October 9 - 16, 1964 - (LRC Full-Scale Tunnel)

Preliminary free-flight tests were made in the Langley Full Scale Tunnel to determine the basic flight characteristics of the model in the clean configuration up to the stall without stability augmentation. The wing sweep was varied from 16° to 72.5° for the tests. (48 hours)

October 9 - 30, 1964

NASA/LRC provided two strain-gage balances with calibration arms

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and fixtures for use by General Dynamics during control effectiveness tests of the 1/24-scale model in the Cornell Aeronautical Laboratory 8-foot transonic pressure tunnel.

October 14, 1964 - (Nozzle Meeting)

NASA/LRC representatives (J. F. Runckel and E. C. Polhamus) attended a meeting at General Dynamics relative to the blow-in-door ejector nozzle performance. The purpose of the meeting was to provide Dr. B. H. Goethert (AFSC Chief Scientist) with the technical background for forming a recommendation to General Zoeckler relative to the nozzle performance problem. Since the nozzle problem was apparently associated with the aircraft aft end flow field and since the aft end drag was rather high, the Langley representatives recommended that improvements in the back end of the aircraft be investigated before an extensive nozzle study was initiated. It was also recommended that a terminal fairing nozzle be considered. Dr. Goethert indicated that a working group would be formed and that it should be concerned with the aft end drag as well as the nozzle.

October 14, 1964

M. L. Spearman visited GD/FW as consultant on F-111 supersonic stability.

October 20, 1964

NASA/LRC representative (E. C. Polhamus) served as a consultant during a meeting at the Bureau of Naval Weapons involving discussions between Navy and F-111 SPO representatives relative to the F-111B performance.

October 22 - November 4, 1964 - (LRC 12-ft. Tunnel)

Force tests were conducted in the LRC 12-foot tunnel to determine the static stability and control characteristics of the model in the clean and landing configurations. These tests were made for five wing sweep angles and over a large angle-of-attack range. The model was also tested over a moderate sideslip range to study methods of improving the high angle of attack directional stability. (80 hours)

October 28 - November 3, 1964 - (LRC 26-in. TBT)

Further flutter studies of the lightweight (SWIP) horizontal tail design in order to refine the stiffness requirements for flutter were made in the Langley 26-inch transonic blowdown tunnel. (40 hours)

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October 29, 1964 - (Nozzle Committee)

The first meeting of the F-111 nozzle committee was held at NASA/LRC on October 29, 1964. Organizations represented on the committee were F-111 SPO, Bureau of Naval Weapons, Pratt and Whitney, General Dynamics, and NASA. NASA members were J. F. Runckel, E. C. Polhamus, and W. E. Anderson. Mr. Runckel reviewed the results of the Langley 16-foot transonic tunnel tests of the hot jet propulsion model and after a discussion the committee outlined the items to be covered in future meetings in an attempt to improve the thrust and aft end drag of the F-111.

November 3, 1964 - (FRC)

NASA/FRC hosted a meeting with representatives of both the F-111 SPO and Air Force Flight Test Center (AFFTC) from Edwards Air Force Base. Purpose of the meeting was to discuss the proposed acquisition of an F-111 airplane by NASA FRC, programs support requirements, and tentative scheduling. The scheduled flight test program on F-111A No. 6 airplane would not allow NASA to have the airplane until December 1966. A rough draft of an agreement between NASA and the Air Force, for bailment of the No. 6 airplane to NASA, was started at this meeting.

November 12 - 13, 1964 - (Nozzle Committee)

The second meeting of the F-111 nozzle committee was held at Pratt and Whitney. NASA members present were E. C. Polhamus, W. E. Anderson, and B. W. Corson.

November 20, 1964

NASA representative (E. C. Polhamus) visited Air Force Systems Command Headquarters to discuss F-111 drag and performance with Dr. B. Goethert (Chief Scientist) and Mr. E. L. Davis (F-111 SPO.)

November 23 - December 11, 1964 - (LRC 16-ft. TDT)

Flutter clearance tests of the empennage of the 1/8 size flutter model were made in the Langley transonic dynamics tunnel. Also, the dummy model of the 1/8 size complete flutter model was tested on the improved suspension system to be used with the complete flutter model. (220 hours)

December 7 - 9, 1964 - (Nozzle Committee)

The third meeting of the F-111 nozzle committee was held at General Dynamics/Fort Worth. NASA members attending were W. E. Anderson, B. W. Corson, J. F. Runckle, and E. C. Polhamus. The large improvement in thrust-minus-drag obtained with the LRC interengine fairing design were described.

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December 8 - 14, 1964 - (LRC Full Scale Tunnel)

Free-flight tests were made to determine the effects of stability augmentation in roll and pitch on the model in the clean and landing configurations. The model was flown at various wing-sweep angles over a wide speed range, including the stall. (40 hours)

December 12 - 21, 1964 - (LRC UPWT)

Supersonic control studies were made for various wing sweep angles in the Langley Unitary Plan Wind Tunnel. (120 hours)

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January 4 - 20, 1965 - (LRC 26-in. TBT)

This entry in the Langley 26-inch transonic blowdown tunnel included flutter clearance tests of the lightweight (SWIP) vertical tail models and also exploratory flutter model tests of the early design (PRE-SWIP) F-111A wing with three different external store configurations. The wing-with-store results showed that small flutter models could be tested with reasonable success in this facility. (200 hours)

January 7 - 8, 1965 - (Nozzle Committee)

The fourth meeting of the F-111 nozzle committee was held at the SPO office, Wright-Patterson Air Force Base. NASA members present were W. E. Anderson, B. W. Corson, and J. F. Runckel. Langley proposed that a concave base interfairing be investigated as a means of reducing drag.

January 18 - February 15, 1965 - (LRC 16-ft. and 8-ft. TT)

During this period, the 1/20-scale model (with annular bleed afterbody lines) was tested in the LRC 16-foot transonic and 8-foot transonic pressure tunnels. For these tests, NASA/LRC contracted with GD/FW for an improved sting support which reduced the model oscillations encountered previously. Since the basic mission performance is critically dependent upon the transonic drag, the primary purpose of the tests in the 16-foot transonic tunnel was to obtain data in a very large tunnel thereby providing essentially "free air" data for use in investigating the highly questionable transonic drag "bucket" obtained in the Cornell 8-foot transonic pressure tunnel. Results were in good agreement with the ARC 11-foot transonic tunnel and indicated no transonic drag "bucket." Previous tests of the configuration with the kidney bleed in the LRC 8-foot transonic tunnel and ARC 11-foot tunnel had also indicated that the transonic drag "bucket" obtained in Cornell was invalid. Pressure tests were also made with and without dummy forward support strut and inlet fairings to evaluate flow field of 1/12 scale afterbody model. Tests indicated no effect of strut or inlet fairing on the nozzle flow field.

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During this period, a few tests were also made in the LRC 8-foot transonic pressure tunnel to provide correlation information between the tunnels. The results were in good agreement at low angles of attack with some differences being noted at the higher angles. (192 hours)

January 22 - 24, 1965 - (LRC 12-foot tunnel)

Preliminary tuft study was made in the LRC 12-foot tunnel to determine the flow characteristics of the wing. (16 hours)

February 15 - 16, 1965 - (Nozzle Committee)

The fifth meeting of the F-111 nozzle committee was held at the Bureau of Naval Weapons, Washington, D. C. NASA members present were B. W. Corson and J. F. Runckel.

February 19 - March 3, 1965 - (LRC 12-foot tunnel)

An extensive tuft study was made of the model in the clean and landing configuration to determine the stall pattern of the wing. In addition numerous fixes were tried on the glove in an effort to change the vortex pattern set up by the glove and also to delay separation on the glove including a translating and rotating glove. (72 hours)

February 22 - March 12, 1965 - (LRC 16-ft. TDT)

Flutter clearance tests of the empennage model and of the 1/8-size complete flutter model of the F-111A/B early prototype (PRE-SWIP) airplanes were made in the Langley 16-foot transonic dynamics tunnel. (184 hours)

February 26 - May 3, 1965 - (LRC 16-ft. TT)

Phase IV of tests of the 1/12-scale hot jet model in the LRC 16-foot transonic tunnel was completed during this period. Primary areas of investigation were a continuation of the blow-in-door ejector nozzles parametric studies and additional studies of modified interengine fairings and speed bumps directed towards optimization of airplane thrust minus drag for the $M = 1.2$ sea level dash. Results indicated only minor improvements in thrust minus drag obtainable through geometric changes in the basic blow-in-door ejector nozzle but rather large improvements associated with airframe changes especially in the region between the nozzles. A brief study of combining the LRC terminal fairing nozzle concept with the Pratt and Whitney blow-in-door nozzle concept was also made. The free floating tail feathers were replaced with terminal fairings and a special interengine fairing was designed for this configuration. The resulting improvements in thrust minus drag were the best obtained to date. (704 hours)

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March 8, 1965 - (ARC)

Mr. E. B. Maske of General Dynamics visited Ames, in response to an invitation, to review the results of recent Ames tests involving the use of vortex generators to control distortion in supersonic inlet systems. It was suggested that the use of vortex generators might also prove beneficial to the F-111 air-induction system which was known to be experiencing propulsion system difficulties due to large distortion. The Ames results were reviewed and Mr. Maske was supplied with the detailed design of the vortex generator system used in the Ames work.

March 10 - 12, 1965 - (LRC Full Scale Tunnel)

Free-flight tests were made to determine the flight characteristics of the model in the landing configuration with rebuilt flaps. In addition the model was flown with a translating and rotating glove and also with various fixes on the glove in order to determine what effect they would have on the stability of the aircraft. (24 hours)

March 18, 1965 - (Nozzle Committee)

The sixth meeting of the F-111 nozzle committee met at Pratt and Whitney. NASA member present was J. F. Runckel.

March 22 - April 2, 1965 - (ARC 11- by 11-foot and 9- by 7-foot WT)

A 1/15-scale model of the reconnaissance version of the F-111A (RF-111A) was tested in the Ames 11- by 11-foot and 9- by 7-foot wind tunnels to determine the effect of various external protuberances on the lateral and longitudinal stability characteristics. The tests were conducted over the Mach number range of 0.6 to 2.5. No significant changes in the lateral or longitudinal stability characteristics resulted from the proposed addition of external equipment to the basic F-111A model. (120 hours)

March 29 - April 30, 1965 - (ARC 6- by 6-foot WT)

A 1/20-scale model of the F-111/SAC proposal was tested in the Ames 6- by 6-foot wind tunnel to determine the drag and longitudinal stability characteristics for Mach numbers from 1.7 to 2.2. The results indicated that modifying the external contours of the basic F-111 was feasible and a substantial drag reduction could be obtained by relocating the external stores from the inboard to the outboard positions. (260 hours)

April 2, 6 - 9, 15, 16, 22 - 29, 1965 - (LRC 12-foot tunnel)

Based on the results of the previous tuft study, which showed a spanwise flow pattern across the trailing edge of the wing at the wing fuselage juncture, additional studies were made with the wing-fuselage juncture sealed. The model was also tested in the landing configuration with a translating and rotating glove. (104 hours)

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April 7, 1965 - (ARC)

Mr. E. B. Maske of General Dynamics visited Ames to discuss the early F-111 flight test results which had been obtained with vortex generators installed in the inlet. A number of different vortex generator configurations had been flight tested and considerable improvement resulted. Additional configurations were recommended for test.

April 14 - 15, 1965 - (Nozzle Committee)

The seventh meeting of the F-111 nozzle committee was held at the Langley Research Center. NASA members present were W. E. Anderson, B. W. Corson, J. F. Runckel, and E. C. Polhamus. The results of the extensive nozzle and afterbody studies in the Langley 16-foot transonic tunnel were reviewed and indicated that no significant gains had been made through nozzle modification but that major gains in thrust-minus-drag could be obtained by improving the engine interfairing and/or speed bumps.

April 21, 1965

A NASA-Navy meeting was held at Washington, D. C., which also included Air Force representatives. Purpose of the meeting was to discuss NASA, Navy and Air Force needs for jet engine thrust measurements on the F-111 airplane. The four basic needs for measuring in-flight thrust on the F-111 airplane are:

- (1) To delineate flight performance as a basis for improvements.
- (2) The need to correlate wind-tunnel and flight results.
- (3) Basic aerodynamic research involving full-scale inlets, exits, and base drag.
- (4) The need for the services to ascertain responsibility for performance deficiency.

A discussion was also held on how the Navy tests, using the swinging tail pipe rakes, fit the overall program.

May - July, 1965 - (LRC)

During this period, representatives of Grumman Aircraft Engineering Corporation visited the Langley Research Center to discuss methods of improving the acceleration and maneuverability of the F-111B. These discussions were in connection with a Navy study contract on the F-111B. Modifications being considered by Grumman included several of the early Langley suggestions such as a modified wing and pivot location, a straightened tail pipe and an improved interengine fairing. In addition, Grumman was looking at a modified horizontal tail, alternate missile arrangements, and an aft fuselage modification. Since the Grumman time schedule required the use of an existing General Dynamics model and

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wind-tunnel tests in August, Langley offered to make the Unitary Plan Wind Tunnel available to both contractors early in August. The earlier test dates were desirable to both contractors and arrangements were made for General Dynamics to build model parts needed by Grumman.

May 10 - 11, 1965 - (Nozzle Committee)

The eighth meeting of the F-111 nozzle committee was held at Grumman. NASA members present were B. W. Corson, J. F. Runckel, and W. E. Anderson.

May 12 - 13, 1965 - (LRC Full Scale Tunnel)

Free-flight tests were made for the model in the clean configuration at 26° wing sweep to determine the most aft c.g. position the model could be flown. Tests were also made to determine the amount of stability augmentation necessary for satisfactory flight in roll. (16 hours)

May 21, 1965 - (LRC Full Scale Tunnel)

Some oscillograph records were made in the Langley full scale tunnel of the variation in rolling moments with time for the model in the clean configuration. (8 hours)

May 24 - June 7, 1965 - (ARC 9- by 7-foot WT)

A 1/15-scale model of the F-111/SAC proposal was tested in the Ames 9- by 7-foot wind tunnel to determine the lateral stability characteristics of this configuration in the Mach number range of 1.7, to 2.5. In addition, the longitudinal stability characteristics at high angles-of-attack were determined. (140 hours)

May 24 - June 23, 1965 - (LRC Full Scale Tunnel)

Forced oscillation tests were made in the Langley full scale tunnel to determine the dynamic stability and control characteristics of the model in roll and yaw. In addition, static force tests were made in the full scale tunnel at a higher dynamic pressure and over a greater angle of attack and sideslip range than was possible in the 12-foot tunnel. (184 hours)

June 14 - 25, 1965 - (ARC 11- by 11-foot WT)

A 1/20-scale model of the F-111/SAC proposal was tested in the Ames 11- by 11-foot wind tunnel to determine the drag and longitudinal stability characteristics in the Mach number range of 0.6 to 1.4. (140 hours)

June 21 - July 16, 1965 - (LRC 26-in. TBT and 20-in. VST)

Flutter clearance tests of lightweight (SWIP) vertical tail models were made in Langley 26-inch transonic blowdown tunnel and in the 20-

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inch variable supersonic tunnel. Also, flutter clearance tests of models of early prototype (PRE-SWIP) F-111A/B wing with 9 different external store configurations were made in the 26-inch transonic blowdown tunnel. (280 hours)

June 23, 1965 - May 4, 1966 - (LRC Helicopter Drop)

A continuing study has been made by the Langley dynamic stability branch of the spin recovery characteristics of two 1/9-scale models of the F-111A by means of the helicopter drop technique. Fourteen drops have been made to date with wing sweeps of 16° to 72-1/2° and the center-of-gravity location varied from full-scale fuselage station of 514.1 to 527.8. The tests were made for a scaled weight of about 50,000 pounds and a simulated altitude of about 30,000 feet.

July 6 - 16, 1965 - (ARC 12-foot WT)

During this period tests were conducted in the Ames 12-foot wind tunnel to determine the aerodynamic loads developed on the F-111 high-lift devices. The 1/12-scale rigid loads model was used and the loads encountered in the approach and landing conditions were measured. (160 hours)

July 19 - 27, 1965 - (LRC Full Scale Tunnel)

For this test period in the tunnel the model was flown primarily in the landing configuration with adjustable flaps. In addition, some earlier tests were repeated to substantiate previous flight results. (56 hours)

July 19 - 30, 1965 - (ARC 12-foot WT)

A 1/12-scale model of the F-111/SAC was tested in the Ames 12-foot wind tunnel to determine the low-speed stability characteristics of this proposed configuration. (160 hours)

August 6, 1965 - (LRC)

A meeting was held at the Langley Research Center to discuss the performance problems associated with the aft end of the F-111A and F-111B and the associated testing to be accomplished in the next series of tests (Phase V) of the hot jet model in the Langley 16-foot transonic tunnel. Organizations taking part were F-111 SPO, Bureau of Naval Weapons, General Dynamics, Grumman, Pratt and Whitney, and NASA/LRC. It was decided that the emphasis for the Phase V testing should be placed on reducing the transonic drag of the F-111A by developing optimum interengine fairing and speed bumps and on studying the possibility of both reducing drag and improving the nozzle environment by straightening the tail pipe. Some tests of fixed shrouds for the F-111B were also recommended. In addition, studies of a new back end and various nozzles for the F-111B were discussed but it appeared that the funding of the model modifications were unsettled.

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August 9 - 27, 1965 - (LRC UPWT)

Tests of the F-111B were made in the Langley Unitary Plan Wind Tunnel. The first portion of this test period was devoted to tests for General Dynamics and included stability, control and missile effects.

The second portion of this test period was devoted to tests for Grumman in connection with their Navy contract to study methods of improving the acceleration and maneuverability of the F-111B. The tests included various semi-submerged missile arrangements, a modified horizontal tail and a modification of the aft fuselage to reduce the gap between the fuselage and the horizontal tail. (232 hours)

August 30 - September 20, 1965 - (LRC Full Scale Tunnel)

Pitching oscillation tests were made in the Langley full scale tunnel for the model in the clean and landing configurations. (128 hours)

September 1 - 17, 1965 - (ARC 11- by 11-foot WT)

A 1/20-scale model of the F-111/SAC A+ (F-111A fuselage with F-111B wings) proposal was tested in the 11- by 11-foot wind tunnel to determine the effect of various store combinations and locations on the drag and longitudinal stability characteristics in the Mach number range of 0.6 to 1.4. Data obtained during this investigation compared favorably with that obtained during past F-111A tests. (128 hours)

September 8 - 9, 1965

The first meeting of the F-111/TF-30 Propulsion Program Review Committee of the Air Force Division Advisory Group was held to review F-111 engine-inlet compatibility problems. The meeting was held at the General Dynamics plant at Fort Worth, Texas. NASA members attending were Mr. E. W. Perkins of Ames Research Center and Mr. Carl Schueller of Lewis Research Center.

September 17 - 30, 1965 - (LRC 8-ft. TPT)

The most promising missile arrangements determined from the UPWT tests were rested at transonic speeds in the Langley 8-foot transonic pressure tunnel. (80 hours)

September 22, 1965

The second meeting of "F-111/TF-30 Propulsion Program Review Committee" was held at Pratt and Whitney Aircraft, East Hartford, Connecticut, to discuss engine control problems, inlet distortion evaluation, engine development and estimated stall free envelope for F-111/TF-30. NASA members present were Messrs. Carl F. Schueller (LeRC) and E. W. Perkins (ARC).

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September 27 - 30, 1965 - (LRC 26-in. TBT)

Flutter clearance tests of lightweight (SWIP) horizontal tail models were made in the Langley 26-inch transonic blowdown tunnel. (40 hours)

September 29, 30 and October 1, 1965 -

The third meeting of "F-111/TF-30 Propulsion Program Review Committee" was held at Wright-Patterson Air Force Base, Dayton, Ohio, to familiarize the committee with other propulsion systems, such as the F-4, B-70 and F-12 and for the committee to make detailed and specific recommendations relative to the F-111/TF-30. NASA members present were Messrs. Carl F. Schueller (LeRC) and E. W. Perkins (ARC).

October 25 - 29, 1965 - (LRC UPWT)

During this period additional tests were made in the Langley Unitary Plan Wind Tunnel directed towards improving the versatility and performance of the F-111B with missiles installed. (80 hours)

October 27 - November 18, 1965 - (LRC 16-ft. TDT)

Flutter clearance tests of 1/8-size complete flutter model of the F-111A/B prototype lightweight (SWIP) airplanes with the clean wing and with 2 external store configurations were made in the Langley 16-foot transonic dynamics tunnel. (236 hours)

November - December 1965 - (LRC Dynamics Stability Branch)

An analytical spin program was started using inhouse low Reynolds number data. The object of this analysis is to correlate analytical results with experimental model spinning characteristics obtained both by radio-controlled models and spin-tunnel models.

November 15 - December 30, 1965 - (LRC 16-ft. TT)

Phase V tests of the 1/12-scale hot jet model were run in the Langley 16-foot transonic tunnel. These tests were directed towards development of the NASA/LRC interengine firings which provide sizable performance improvements and tests of the configuration that were to be flight tested early in 1966. Tests were also made of a modified nacelle-nozzle-interfiring combination for the F-111B in support of the Navy study contract. (704 hours)

November 29 - December 17, 1965 - (ARC 9- by 7-foot WT)

The 1/12-scale rigid loads model was tested in the Ames 9- by 7-foot wind tunnel to obtain external store loads, redesigned weapons bay door loads and weapons bay store loads during store ejection. The tests covered the Mach number range from 1.6 to 2.5. The loads on the

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redesigned weapons bay doors were approximately the same as loads measured on the previous doors. No significant changes in door loads occurred as the various stores were translated out of the weapons bay. The weapons bay stores were longitudinally unstable until extended further than 90 inches (full-scale) from the airplane. (300 hours)

November 30, 1965

Representatives of the Flight Research Center Flight Loads Section assembled an air loads flight program at the request of the F-111 SPO and made the presentation of same at Wright-Patterson Air Force Base. The FRC air loads flight program would accomplish the 80 percent air load test requirements in the specified length of time, namely, to have the major portion of the program data plotted and analyzed by July 1, 1966.

December 16, 1965 - (LRC - UPWT)

Tests of the F-111B in support of the Navy sponsored study contract with Grumman were continued in the Langley Unitary Plan Wind Tunnel. This study was directed towards improving the supersonic performance and directional stability of the F-111B with missiles installed. (16 hours)

December 20 - 24, 1965 - (LRC 8 ft. TPT)

Transonic tests in support of the Navy sponsored study contract were made on the F-111B in the Langley 8-foot Transonic Pressure Tunnel. (16 hours)

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1. Staff, Langley Research Center: Summary of NACA/NASA Variable-Sweep Research and Development Leading to the F-111 (TFX). LWP-285.

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TABLE I

NASA WIND-TUNNEL SUPPORT OF
F-111 IN TERMS OF TUNNEL OCCUPANCY HOURS

	1963	1964	1965	TOTAL
<u>Langley Research Center</u>				
16' TT	1,230	2,056	1,558	4,844
UPWT	1,361	1,352	328	3,041
26" TBT and 20" VST	616	540	520	1,676
Spin Tunnel		800	774	1,574
8' TPT	768	504	138	1,410
16' TDT	480	300	420	1,200
Full Scale Tunnel		88	416	504
7' x 10' HST	272			272
12' T	80		192	272
4' SPT	32			32
LANGLEY TOTALS	4,839	5,640	4,346	14,825
<u>Ames Research Center</u>				
11' x 11' WT	310	732	328	1,369
12' WT		666	320	986
6' x 6' WT	84	628	260	972
9' x 7' WT		560	500	823
AMES TOTALS	394	2,586	1,408	4,388
<u>Lewis Research Center</u>				
8' x 6' WT		480		48
10' x 10' WT		240		240
LEWIS TOTALS		720		720
NASA TOTALS	5,233	8,946	5,754	19,933

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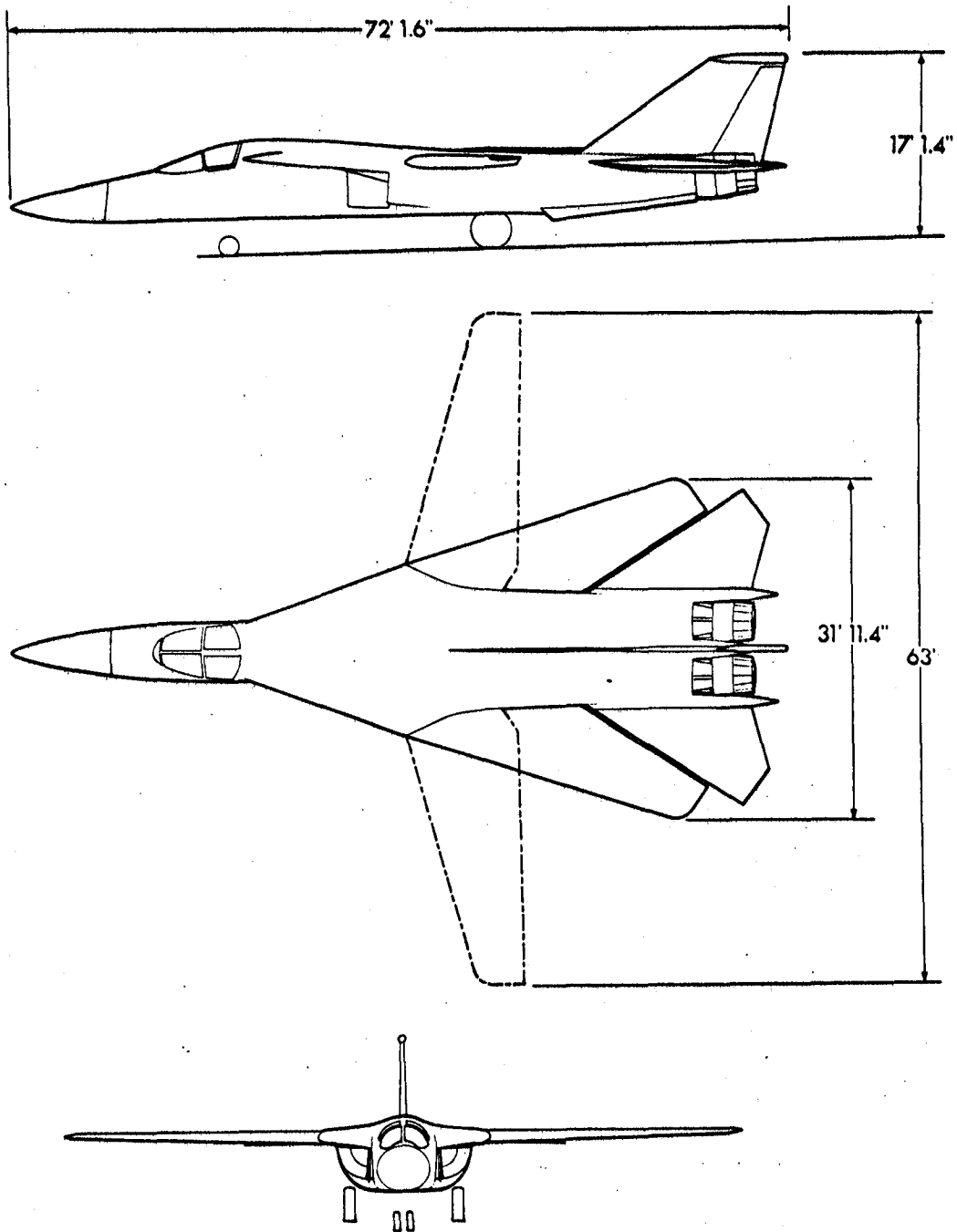


Figure 1. - General arrangement of F-111A.

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